TECHNICAL DESIGN CONCEPTS TO IMPROVE HELICOPTER OBSTACLE AVOIDANCE AND OPERATIONS IN "BROWNOUT" CONDITIONS

This invention claims priority to U.S. Provisional Patent Application 60/458,257 dated March 31, 2004.

Background of the Invention

Field of the Invention

This invention relates generally to flight control systems and display systems for vertical take off and landing capable aircraft.

Description of the Prior Art

Hazardous weather conditions significantly limit the operational capability of helicopters. Helicopters are called upon routinely to approach and land at remote sites without the aid of navigation guidance or acceptable and safe visual conditions. Often the topography, ground hazards, obstacles and weather in the area are unknown or changing. Upon arrival at a remote location, the pilot must make critical judgments based on incomplete or inaccurate data available to him in order to determine the proper procedure to approach and land at the site. If the surface condition is such that dust, snow, sand, etc. will be blown up by rotor downwash, the helicopter is often suddenly engulfed in a cloud of visually-restrictive material, causing the pilot to lose his visual references. The loss of visual references causes spatial disorientation problems that impede a pilot from making a fully stabilized safe landing.

The pilot uses his visual references for determining his control strategy to stabilize and bring the aircraft to a prelanding quiescent trim condition and to establish his ground closure rates as he finalizes his approach and touches down. In interviews with pilots, it was determined that pilot workload and procedures such as cross cockpit checks increase during a tactical

tactical "brownout" landing. When references are lost, a pilot may know his attitude references, but he is most likely unaware of his fore and aft, lateral, and vertical speed relative to the ground. He may also not be aware of the local terrain contour for a safe all wheel settling to the ground.

This has prevented many helicopter pilots from completing missions, or even losing control of the helicopter causing injury, and, in some cases, death and loss of the helicopter.

This limitation partially arises from the crew's inability to determine the location of obstacles in the environment by sight. In order to assist the crew in these circumstances, a range of equipment and sensors may be installed in the helicopter to provide information about the helicopter's position and the position of obstacles. The information provided by the sensors is inherently inaccurate at least because of the time delay in the system but also because of the uncertainty associated with sensor. As the dynamics of the obstacles cannot be guaranteed to be linear, these process models must be capable of reflecting this non-linear behavior. The uncertain information produced by various sensors is related to required knowledge about the obstacles by a sensor model however this relationship need not be linear, and may even have to be learned.

In order to limit the inaccuracies, current helicopter flight control systems use estimation techniques to counteract the error in the sensors. One of the best currently used techniques, an ordinary extended Kalman filter, is inadequate for estimating the uncertainty involved in the obstacles' positions for the highly non-linear processes under consideration. Neural network approaches to non-linear estimation have recently allowed process and sensor models to be learned; however, these approaches are also inadequate.

A shortcoming of the prior art is that with multiple sensors on board, there is a problem of efficiently assimilating the large amount of imagery and data available.

Additionally, another shortcoming of the prior art is the high demand that the scanning of multiple flight instruments places on a pilot. When in a brownout situation, the pilot must focus himself on multiple flight display instruments in order to compensate for his lack of visual landing references.

Yet another shortcoming of the prior art is the mechanical control of the helicopter. Currently, in contrast to modern airplanes, helicopters are either normally mechanically or hydro-mechanically controlled. The partial authority of the flight control system on such helicopters limits the ability of the flight control stability augmentation system to aid the pilot in high workload situations.

Prior to this invention, pilots heavily relied on repetitive training to help them with lost visibility outside the cockpit, for example "brownout". In addition to training, helicopter and avionic manufacturers have tried to help pilots effectively deal with brownout. They have proposed several partial solutions, but they have been incomplete or ineffective in dealing with the brownout problem. Some of these attempts include hover displays with velocity and acceleration cues, coupled hover landings using radar altimeter and Doppler coupled autopilots, and FLIR turret vertical lookdown imaging and improved stability augmentation. Full implementation of these individual ideas have not resulted in a full-proof solution to allow a pilot to fly in a degraded visual environment (DVE). None of the proposed prior art solutions have fully addressed the spatial disorientation problem much less allowed a pilot to make a fully stabilized safe landing.

Summary of the Invention

The present invention recognizes and addresses the foregoing disadvantages, and other prior art methods.

Accordingly, it is an object of the invention to solve acute DVE problem plaguing helicopter operations causing significant loss of life, injury and equipment, most recently in Iraq and Afghanistan. The US Army, USAF and USMC have experienced multiple accidents attributed to dust blown (or snow-blown) conditions which blind pilots entering a hover.

Another object of the invention is to provide a DVE solution when night vision goggles are used.

Still another object of the invention is to provide a DVE solution based on a spectrum of sensor inputs.

Yet another object of the invention is to provide a DVE system that contains a processor that is functional with any combination of sensors typically found on a helicopter to reduce the customization of the system.

And yet another object of the invention is to reduce the data workload through automatic assimilation (sensor fusion) of data.

And another object of the invention is to provide a system for guiding a pilot along an obstacle free path.

And still another object of the invention is to provide a system that more accurately predicts positions of objects and a pilot's relation thereto.

These and other objects of the present invention are achieved by providing a DVE solution with augmented visual cues and advanced flight control systems. The system for guiding pilots in DVE situations includes an array of sensors providing inputs to a central processing unit, the CPU, which processes the data from at least two sensors, provides an output to a hover display, and the hover display which guides the pilot to a safe landing.

Other objects, features and aspects of the present invention are discussed in greater detail below.

Additional objects and advantages of the invention are set forth in the detailed description herein, or will be apparent to those of ordinary skill in the art.

Description of the Drawings

Figure 1 is system architecture block diagram of an embodiment of the invention.

Figure 2 is one embodiment of a hover display.

Detailed Description of the Preferred Embodiments

It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only and is not intended as limiting the broader aspects of the present invention. The broader aspects are embodied in the exemplary construction.

Preferably, the system for flight in DVE comprises a plurality of suites that when interconnected the system functions to help pilot 116 operate the aircraft. Typically, the suites that would be incorporated in the DVE system are suites for flight control, display, sensors, navigation data fusion and display processing, and control.

The flight control suite provides a stabilized flight control system. The flight control includes special control logic to enable a pilot to command a stabilized flight path, hold hover position and altitude, and execute a vertical landing in zero or near zero visibility. Additionally, variable limits are implemented in the control system based on the height of the aircraft above ground and its rate of descent.

The display suite can be implemented in a number of ways, however, there are two preferred displays. The first is a head-mounted display with sufficient field of view that provides visually coupled information to the pilot to augment the natural out-the-window view. The information presented on the helmet is stabilized in conformity to the outside scene through the

utilization of a head-tracking device. Preferably, the device also permits the pilot to cue the on board processor to points of interest the pilot is viewing in the outside scene. The helmet display may be augmented by other panel-mounted displays to enable transfer of information to the processor suite. The second preferred embodiment is a head up display (HUD) with generally the same information.

The sensor suite is used to survey the outside scene and to provide environmental and other information to the pilot to augment visual cues. This information is presented in the form of synthetic imagery which overlays the outside scene, and/or symbology which cues the pilot as to the proper actions to employ to complete a task. The sensors may comprise a radar altimeter, air data system, inertial navigation systems, traffic alert and collision avoidance system, terrain database, global positioning system, microwave radar, 35 GHz wave scanning beam radar, a forward looking infrared camera, and video camera.

The navigation suite relies on the sensor suite to provide precise navigation information, including groundspeed, ground track, wind direction and speed, location of the landing zone, location of other aircraft in the formation, aircraft performance (power required to hover, power available, etc), vertical velocity, height above ground, etc. The information provided to the pilot is information that cannot normally be gathered by purely visual attentiveness during the approach and landing, especially in DVE conditions.

The data fusion and display processor suite incorporates the unique logic and algorithms. It fuses together the wide variety of information available from the various sensors, and displays it so that it can be used and interpreted by the pilot for approach and landing. The processor suite filters sensor and navigation information, and converts it into a format for pilot display. This suite fuses sensor imagery, and, if appropriate, creates symbology that directs the pilot to conduct tasks in such a way as to complete the approach/landing.

The control suite comprises a series of controls that are employed to enable a pilot to request information from the system, or convey intent, so the processor suite may determine what information is to be presented, at what time, and in what format for the task at hand.

Referring now to Figure 1, one can see a system architecture diagram of an embodiment of the system to fly in DVE 100. The system comprises a data bus 102 with inputs from a variety of sensors, a mission computer or CPU 106, intelligent data fusion processor 110, sensor conditioning and filtering 108, fly by wire (FBW) flight control system 104, and a Forward Looking Infrared System (FLIR) 112.

The pilotage of the helicopter using the FBW system 104, the FBW system 104 preferably has certain inputs in order to aid the pilot is his control of the aircraft. The first main input is from the data bus 102. The data from the data bus may include air data, GPS information, a radar altimeter, obstacle avoidance equipment, Enhanced Ground Proximity Warning System (EGPWS)/Controlled Flight Into Terrain (CFIT), digital map, and Differential Global Positioning System (DGPS) among others. The data bus data is fed to a mission computer 106, which outputs signals to the FBW system 104 to manipulate a vertical take off and landing capable vehicle in close proximity to terrain, and to a sensor conditioning and filtering system 108 that processes the data to produce an improved data signal. The mission computer 106 and the sensor conditioning and filter system 108 provide data to a data fusion processor 110, which analyzes the data and compiles the different data into a combined output. For example, when there is both FLIR and visual data, the data fusion processor combines the data into a single picture shown in hover display 114. That hover display 114 may be displayed in a head mounted display 120 or on a head's up display. Additionally, the fusion processor 110 provides information to the FBW system 104. The combined environmental information and mission-specific information may be used to automatically manipulate a vehicle such that

obstacles are avoided. This is very easily done with a FBW system.. The fusion processor and the FBW system both provide data so that a display 118 as shown in more detail in Figure 2 may be created. The display 118 may also be provided for display in a HMD 120.

While the RAH-66 Comanche helicopter was using a helmet-mounted display that incorporated contact analog flight symbology to maintain continuous heads up, eyes out posture, most systems continue to use head down displays and/or non-head tracked symbology (HUDs).. Therefore, a head down approach to hover and hover display is also included. The intent of this display is to provide the pilot with precise pilotage cueing to the approach to hover, with reference to aircraft velocity, location relative to the planned landing point, altitude and rate of descent. More importantly, trend information is provided as a means to assist the pilot in seeing the future state of the aircraft. Overlaid on the trend information is command cueing to indicate what the optimal trend is at the current point in the profile. Additionally, the display would provide a pilot with visual indicators such that the operator is aware of unsafe landing areas.

The display shown in Figure 2 below provides this information in a single, integrated data set. In this display, the aircraft is close to the desired landing point, however it is translating to the right, away from the desired point. The deceleration rate is within tolerance for the current altitude. The rate of descent indicates a trend which predicts the altitude to be approximately 20 ft Above Ground Level (AGL) several seconds in the future. The commanded descent rate for the current point of the profile is slightly higher than the current rate of descent. If the pilot increased the rate of descent to the point where the trend line met the desired trend pointer, the aircraft would be on the correct descent profile. A text field at the bottom of the display provides quantitative readout of critical information (current altitude, rate of descent, ground velocity). This is simply to add to situation awareness.

Advantageously, the system of the present invention uses a unique combination of sensor, navigational and display data enhancing the situational awareness of pilots operating VTOL aircraft while minimizing impact to the pilot's workload.

It should be appreciated that modifications and variations to the specifically illustrated and discussed structure may be practiced in various embodiments and uses of this invention without departing from the spirit and scope thereof. Such variations may include but are not limited to, substitution of equivalent structure for those shown or discussed and the repositioning of various elements, or the like.